AN INVESTIGATION OF THE EFFECT OF FABRIC CONSTRUCTION ON THE COLOR FASTNESS OF VAT DYES APPLIED TO COTTON CLOTH

A THESIS

Presented to

the Faculty of the Division of Graduate Studies

Georgia Institute of Technology

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

John Edmund Collins

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Date Approved by Chairman June 6, 1950

ACKNOWLEDGMENTS

On the completion of this work I wish to express my gratitude to the Southeast Section of the American Association of Textile Chemists and Colorists for their cooperation on this problem. I especially wish to thank Dr. James L. Taylor for his assistance and guidance. I wish also to extend thanks to the Pepperell Manufacturing Company for furnishing the base materials and finishing the cloth, and to Mr. L. A. Burroughs of the E. I. du Pont de Nemours and Company for his able assistance in dyeing the cloth and analyzing the results of these investigations.

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AN INVESTIGATION OF THE EFFECT OF FABRIC CONSTRUCTION ON THE COLOR FASTNESS OF VAT DYES APPLIED TO COTTON CLOTH

INTRODUCTION

Due to the physical separation of the major functions of gray cloth production, finishing, and fabrication, there is little correlation between the physical and the chemical requirements of textile fabrics. Although technical men will admit that at least small variations in color fastness may exist because of differences in fabric construction, there is little evidence of scientific exploration of this problem.

Sparks[1] states that there is a great need at the present time for more fundamental research into both the fastness of dyes and the relation between the physical and the chemical characteristics of textile fabrics.

Dyeing is a very important operation in a highly competitive industry. The dyer is continually pressed to match the rapid progress being made in the development of new fibers, new blends, and new uses for fabrics. To him it is becoming more and more essential to be able to produce faster colors more cheaply. If, therefore, variations in fabric construction affect even to a very slight degree the results he is endeavoring to achieve, it behooves him to investigate them. Differences

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[1] C. E. Sparks, "Need for Fundamental Research," Proceedings of the Meeting of the Textile Research Institute, [illegible]

which today are considered insignificant, may by tomorrow become sizeable distinctions, measurable in dollars and cents.

It is the purpose of this paper to determine how the factor of fabric construction affects the color fastness of the dyed cloth.

A. Method of Attack

In these investigations an effort has been made to produce specimens of cotton cloth of uniform dyeing characteristics, differing only in physical construction. Cotton yarns blended from the same lot of raw stock were woven in one continuous strip on the same warp and with the same loom. Three types of weaves, Plain, Twill, and Sateen, were made. Within each weave, a loose, a tight, and a medium construction was obtained by varying the picks per inch.

This gray fabric was then finished in three groups -- unmercerized, half-mercerized, and fully mercerized. This variation was prompted by the fact that all are treatments commonly used on dyed fabrics.

Two selected vat dyes were then applied to all specimens by the pad-steam process.

Testing for color fastness to light was performed in a standard Atlas fade-ometer. Fastness to washing was tested by means of a "washwheel" or "scrub" test -- a method widely used to evaluate dyed fabrics.

The resulting fading was then examined visually and by means of a photovolt reflectometer.

B. Review of the Literature

Many references may be found in current literature concerning the effect of factors such as fiber structure and resin treatments on the chemical characteristics of the dyed fabric. However, very little material can be found concerning the effect of cloth construction on fastness characteristics.

Zimmerman,[2] in a laboratory study of padding, concludes that differences in constructions and weights affect the pick-up in dyeing because of variations in the porosity of the cloth and in the rates of wetting-out. Again, Work[3] discovered that unoriented and oriented yarns behaved in dyeing in a similar manner to immature and mature cotton fibers. He holds, therefore, that the degree of orientation may be a cause of the variations in the dyeing characteristics of the fabric.

Although the infrared area of the sun's spectrum affects the fading of cloth,[4] Wilhelm[5] has found that the transmission (and hence the absorption) of these rays is affected only by the nature of the fiber and by the average number of fibers in the path of illumination and not by the fabric construction.

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[2] C. L. Zimmerman and G. L. Royer, <u>Effect of Fabric Construction on Dyeing</u> (Calco Bulletin No. 808).

[3] Robert W. Work, "The Effect of Variations in Degree of Structural Order on Some Physical Properties of Cellulose and Cellulose Acetate Yarns," <u>Textile Research Journal</u>, 19:393, July, 1949.

[4] "Coulourist," "Effect of Light on Colours and Fabrics," <u>Textile Manufacturer</u>, 73:278, June, 1947.

[5] R. H. Wilhelm and J. H. Smith, "Transmittance, Reflectance and Absorptance of Near Infrared Radiations in Textile Materials," <u>Textile Research Journal</u>, 19:73, February, 1949.

EQUIPMENT

A. Weaving

Loom: Draper dobby, single cylinder, double index, automatic.

B. Finishing (located in Pepperell Finishing Mill, Pepperell, Alabama)

All equipment was of a modern continuous open-width type.

Singeing Range:	Gas-fired, dual range equipped with a temperature-controlled stop motion.
Desizing:	One-Dip Padder.
Scouring:	Caustic Saturator. "J"-Box.
Mercerization:	Padder. Caustic Saturator. Tenter Frame. Three Williams Units.
Bleaching:	Saturator. "J"-Box. Two Williams Units. Drying Cans.

C. Dyeing

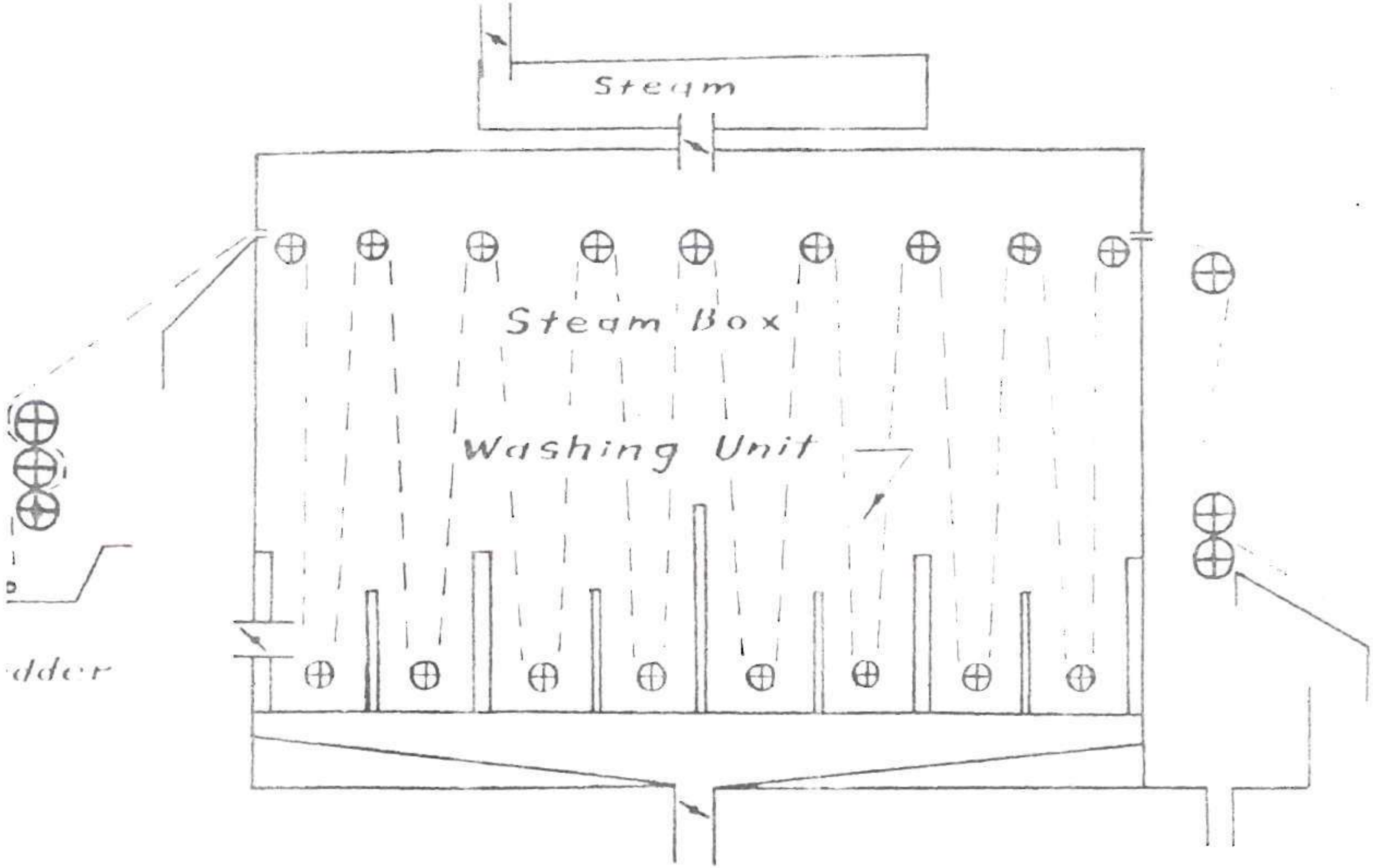
Laboratory model Pad-Steam dyeing machine.

D. "Wash-Wheel"

Washing machine of the cylindrical, reversing type, equipped with a pipe for injecting live steam (wheel diameter = 24 inches).

E. Atlas Fade-Ometer, Model FDA-R.

F. Photovolt Reflectometer, Model 610.



Model Pad-Steam Machine

FIGURE 1

MATERIALS

A. Warp and Filling Yarns

1. Yarn Counts

Warp: 19.7's
Filling: 20.1's
Selvage: 22.8's/2

2. Number of Ends in Warp

Body of Cloth: 2160 Ends
Selvage: 24 Ends
Total: 2184 Ends

For analysis of yarn and other details see Table I.

B. Dyed Cloth

1. Weaves

Plain
Twill, 2/1 right hand
Sateen, modified (1-3-5-2-6-4)

2. Constructions for Each Weave

Tight
Medium
Loose

3. Degrees of Mercerization for Each Weave

Unmercerized
Half-Mercerized
Fully Mercerized

For cloth counts see Table III.

C. Dyes

1. Ponsol Khaki 2G, Double Paste, (du Pont)

2. Ponsol Brown AG, Double Paste, (du Pont) I.C. No. 1152

D. "Wash-Wheel" Test

1. Chip Soap (one pound per gallon of water used)

TABLE I

ANALYSIS OF COTTON STAPLE AND YARN

COTTON ANALYSIS		
STAPLE	Array Method	
	Length at 25% Point:	1.168"
	Mean Length:	.956"
	Coefficient of Variation:	31.35%
	Fibrograph Method	
	Upper Half Mean Length:	1.08"
	Mean Length:	.76"
	Uniformity Ratio:	70.37%
FIBER MATURITY (% Mature Fibers)	Polarized Light Method	82%
	Sodium Hydroxide Method	71%
FIBER FINENESS (Micrograms/Inch)	Micronaire Method	4.5
	Suter-Webb Sorter Method	4.4

YARN ANALYSIS		
	Warp	Filling
Actual Yarn Number	19.7's	20.1's
Actual Twist Multiple	4.29	4.25
Yarn Evenness	82.00%	81.00%

EXPERIMENTAL PROCEDURE

A. Weaving

The warp and filling yarns were donated by the Lindale Mill of the Pepperell Manufacturing Company. All yarns were blended from the same lot of raw cotton. In this way, the variables in dyeing characteristics due to fiber differences were minimized.

All the cloth was woven in one continuous strip with the same Draper dobby loom on the same warp. Six harnesses with a straight drawing-in plan were used for all weaves. Moreover, the same reeding plan of four ends per dent obtained throughout.

Conversion from one weave to another was effected by changing the pegging plan on the harness chain. Picks per inch were varied by changing the pick gear. All possible variables due to machine operation were thus eliminated.

The weaves chosen were Plain, Twill, and Sateen, these being considered the most common ones in popular use. The six harnesses were chosen because this was the smallest number that could be used to produce all weaves.

The selvage at each side of the cloth consisted of 12 plied ends and 8 double ends. A plain selvage was used for the plain weave, and a tape selvage for the twill and sateen. Four harnesses were used for the tape selvage.

Operating conditions were maintained with the temperature range of 74°-82°F and relative humidity range of 71%-79%. The loom speed averaged 142 rpm.

B. Finishing

Finishing of the fabric was carried out on the continuous open-width ranges of the Pepperell Manufacturing Company in Pepperell, Alabama. Singeing was effected on an automatic, gas-fired range, with a temperature-activated stop motion. Both sides of the cloth were singed at 140 yards per minute.

Next, the cloth passed through the desizing range. The process consisted of one dip (with no squeeze) into a bath of 1/2 per cent Rhozyme LA and 1/12 per cent Triton X-100 at 150°F. Steeping took place in a hand truck for 45 minutes. Then followed a hot water wash in a Williams Unit.

Scouring was performed at 75 yards per minute in a caustic saturator containing 3 to 3-1/2 per cent sodium hydroxide, followed by a storage of 45 minutes in a "J"-box at 205°F. The moisture pick-up was 100-110 per cent. At this point the cloth was divided into three groups. One was left unmercerized.

Mercerization was performed at 75 yards per minute on the other two groups. Half-mercerization was effected at 30°tw on the second; full mercerization at 54°tw was applied to the third. The cloth was first wet-out by one dip and one nip in a hot water bath and then given two dips and two nips in the caustic bath:

Half-Mercerization:	30°tw 94°F
Full Mercerization:	54°tw 116°F

Next followed a passage over a heated tenter frame, with four warm water baths of the "suction" type at the latter end. Finally the cloth was given a hot water wash in three Williams Units. The finished width was

Bleaching was carried out at 75 yards per minute, with first two dips and two nips in a bath of 9 pounds per gallon of Albone 35 (hydrogen peroxide) and 14 pounds per gallon of sodium silicate. After this, the goods were stored for 45 minutes in a "J"-box. Finally, a hot water wash was given in two Williams Units, and the goods were dried on drying cans.

C. Dyeing

All the test specimens were dyed with vat colors on the continuous model pad-steam machine in the Atlanta laboratory of the E. I. du Pont de Nemours and Company. All material was given the same treatment, except that varying amounts of pigment were applied to the different degrees of mercerization.

In the selection of dyes, four requirements were considered. The colors had to be in common use for clothing fabrics, easily applied, level dyeing, and readily duplicated.

Two typical vat colors were found to meet these qualities:

(1) Ponsol Brown AG, Double Paste: a dye widely used in those civilian and military fabrics that require the highest fastness to light and washing.

(2) Ponsol Khaki 2G, Double Paste: a widely used color, having a lower degree of wash fastness.

The apparatus used was the laboratory model pad-steam dyeing machine shown in Figure 1. This was built to duplicate the conditions in a full-sized pad-steam machine. The single padder was used both to pad the dye pigment and to impregnate the reduction solution. The steam-box unit was converted to a continuous washing unit by closing the steam inlet and opening the water valves.

In order to determine the dyeing characteristics of each cloth, padded pigment migrated in drying in the places where the cloth had creased. Precautions were therefore taken in the regular dyeing runs to avoid this occurrence.

In the dyeing procedure, the clothshaving different constructions were processed in three continuous strips, one for each degree of mercerization. The pigment was applied in the padder at 140°F at the rate of 12 feet per minute. In preparing the bath, the following amounts of the dye paste were weighed out, and then dispersed in a 4-liter bath by stirring, straining, and heating to 140°F:

Unmercerized: 3.0 oz/gal.
Half-Mercerized: 2.7 oz/gal.
Fully Mercerized: 2.25 oz/gal.

The padded fabric was then rolled on a hand reel, and carefully hung up to dry on wires strung up in the laboratory for that purpose. All air currents were eliminated by closing all outlets and stopping the electric fan.

When dry, the strips of fabric were sewn together and passed in one group through the reduction process. Flake caustic soda and du Pont hydrosulphite were dispersed with du Ponol WA paste in a 6-liter bath, and heated to 140°F. Color pigment in the amount of 5 per cent by volume was added to the reducing bath to prevent migration of the padded pigment from the cloth. The cloth was then impregnated in the padder with one dip and two nips at 140°F. The bath was continuously replenished, in order to keep the percentage of pigment therein constant.

After two cold water washes in stainless steel tubs, with subsequent squeezes in a wringer, the fabric was oxidized with 1/2 ounce per gallon of sodium perborate at 120°F for 20 minutes in a stainless steel tub.

Then the material was scoured and rinsed in the steam box converted into a continuous washing machine. Scouring took place in a bath of 1/2 ounce per gallon of neutral soap flakes, with four dips and two nips at 200°F. Finally a cold water wash with four dips and two nips was given in the same washing unit.

D. Testing

All specimens were tested for comparative color fastness by methods commonly used in the dyeing and finishing industry.

1. Testing for Color Fastness to Light

In general, all samples for each comparison were exposed together, under the same conditions in a standard Atlas fade-ometer. This method of attack eliminated all the machine variables due to factors such as temperature, humidity, clouding of the glass globe, and fluctuations in the power source.

Furthermore, each machine run was calibrated to determine the equivalent number of standard fading hours, by means of Light Sensitive Paper No. 1554, currently used by the National Bureau of Standards as the fading standard for textiles. Measurement was made of the reflectance of all papers, in terms of magnesium oxide as a standard, on a photovolt reflectometer, using an amber filter. The results were plotted on the standard fading curve[6] for the paper, and the corresponding abscissas determined. These represented the number of standard fading hours that would have caused the same degree of fading.

[6] Standard Fading Curve for Light Sensitive Paper No. 1554, Un-

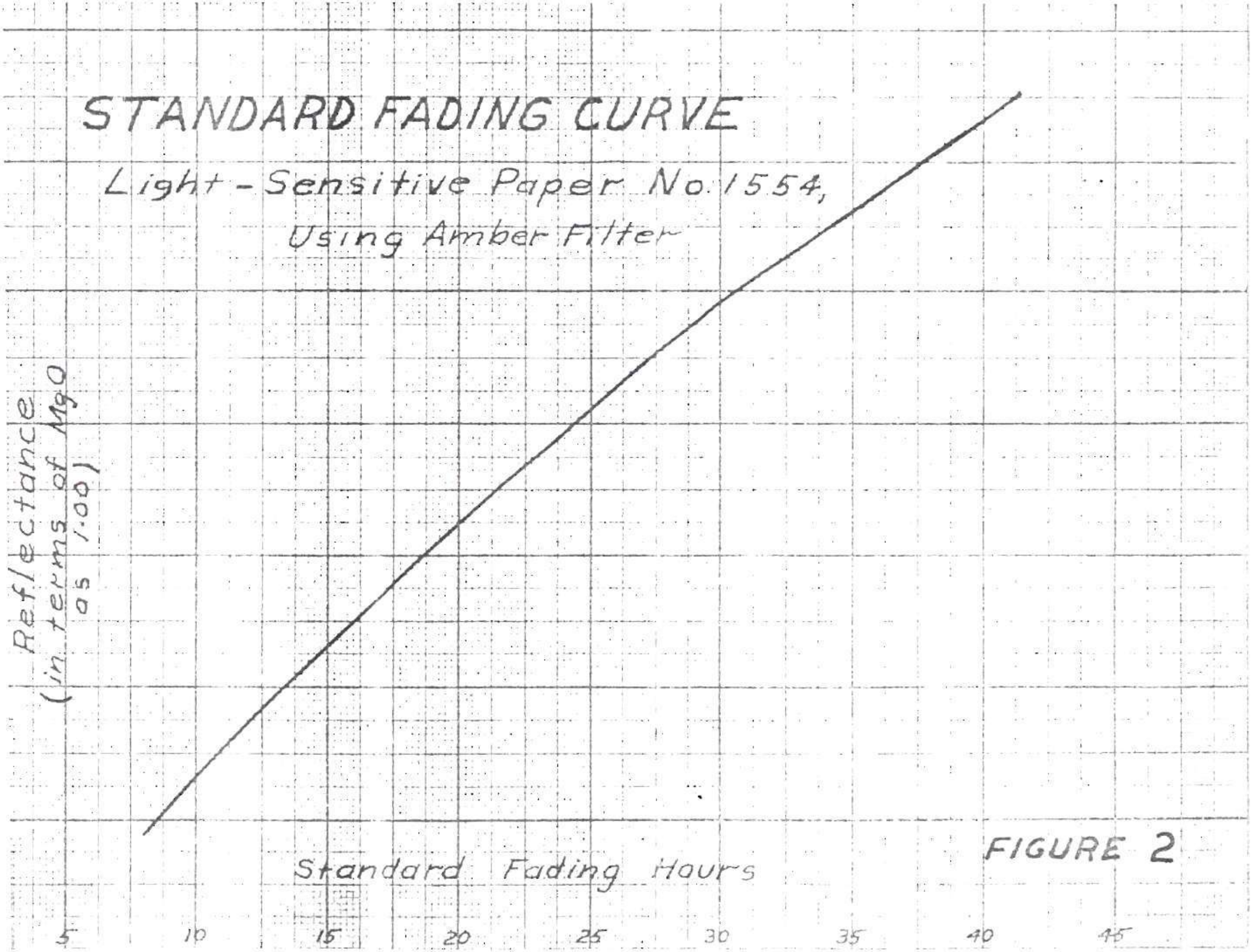

STANDARD FADING CURVE
Light-Sensitive Paper No. 1554,
Using Amber Filter
Reflectance
(in terms of MgO
as 1.00)
Standard Fading Hours
5
10
15
20
25
30
35
40
45

FIGURE 2

Thirty-three calibrations in all were made. Numbers 1-15 were verified by having the papers sent to the National Bureau of Standards. The results compared very closely with those determined on the photovolt machine.

Two methods of attack were used in measuring the fastness to light. In one, the point of initial fading or "break" point was determined. In the other, an examination was made of the behavior of the samples at fixed points of fading.

a. Determination of Initial Fading Points

Each set of samples was exposed together in successive periods of approximately 15 standard fading hours. At the end of each period the samples were visually examined for fading in the same room near a north window. Light conditions were chosen as closely as possible to moderately blue northern light. Two degrees of fading were determined: (1) barely perceptible fading -- that which was not discernible at first glance, but was detected after intent examination, with the plane of the sample being rotated to facilitate observation; (2) readily discernible fading -- that which was evident at once when the specimen was held at arms length at right angles to the line of vision, with the light source striking the sample at an angle of 45°.

b. Quantitative Examination of Fading

In this test a separate set of specimens was exposed for each of three widely separated periods:

Ponsol Brown AG: 81-110-238 Standard Fading Hours.
Ponsol Khaki 2G: 109-137-225 Standard Fading Hours.

All samples and their controls were then placed on a table under northerly light and examined visually for relative fading.

Attention was focused on the quantitative loss of color, hue changes such as "redder" and "greener", and loss of brightness. Samples were classified according to the light classes of fastness listed by the American Association of Textile Chemists and Colorists.

2. Testing for Color Fastness to Washing

For this purpose, all samples were passed through the "wash-wheel" test at the du Pont laboratory in Charlotte, North Carolina. This method of testing was chosen because it is the one commonly used by the dyeing and finishing industry to test its own products for fading and shrinking.

Two sets of samples of all constructions were sewn to an unsized, white base cloth. One set was given one wash; the other set was given five washes. Each wash consisted of a 60-minute run in a cylindrical, reversing, 24-inch "wash-wheel", equipped with a pipe for injecting live steam. The machine was first loaded with the specimens and started. Then water and soap in the amount of one pound per gallon were added, after which the temperature was raised to 212°F with live steam. The steam was then shut off, and the machine run until the 40-minute point was reached. The soap solution was then drained without stopping the machine, the latter refilled with water, and the temperature raised to 140°F. After five minutes the draining, refilling, and heating were repeated. At the end of 55 minutes of total, elapsed time, the machine was again drained and permitted to run until it reached the 60-minute point.

The cloth was then extracted and dried, and pressed under a damp cloth with a hand iron.

An examination of comparative fading was made by placing all samples with their unfaded controls on a table near a northerly window. Then they were examined visually and classified as to the degree of fading by the method practiced by the E. I. du Pont de Nemours and Company. Particular attention was paid to the quantitative loss of color, with observations of changes in brightness and in hue, such as "redder" or "greener". Ratings were assigned from 1 to 5 as shown in Table VII.

DISCUSSION OF RESULTS

A. Light Fastness Tests

1. Initial Fading Points

The results of this test are shown in Table IV and in Figures 3, 4, and 5. In general there was an upward trend from the tight weave fading at an early point to the loose weave fading at the highest point. This trend is not a straight line curve, however. That of the tight and medium weaves lay close together, but the loose weave faded at a considerably higher point.

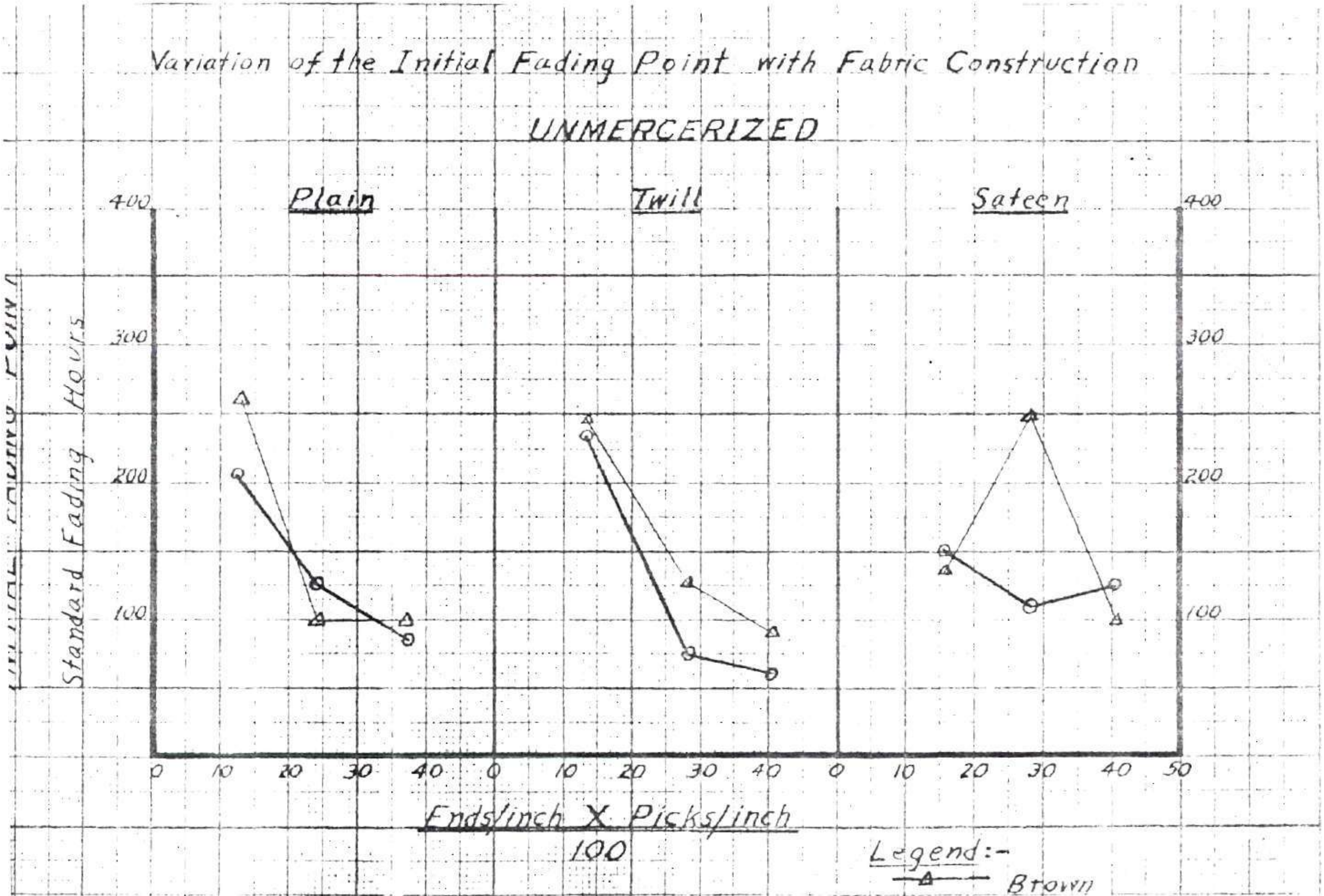
The trend was the same in all three degrees of mercerization, with the point of initial fading lying generally higher in the higher degrees of mercerization.

One outstanding result of the test was that the sateen loose weave fully mercerized did not show any traces of perceptible fading at 296 hours.

The khaki color had the same trend throughout. The brown had similar results for all plain weave variables; but for the twill weave it showed consistent results only in the unmercerized and half-mercerized groups. For the sateen weave only in the half-mercerized and fully mercerized groups were uniform results obtained.

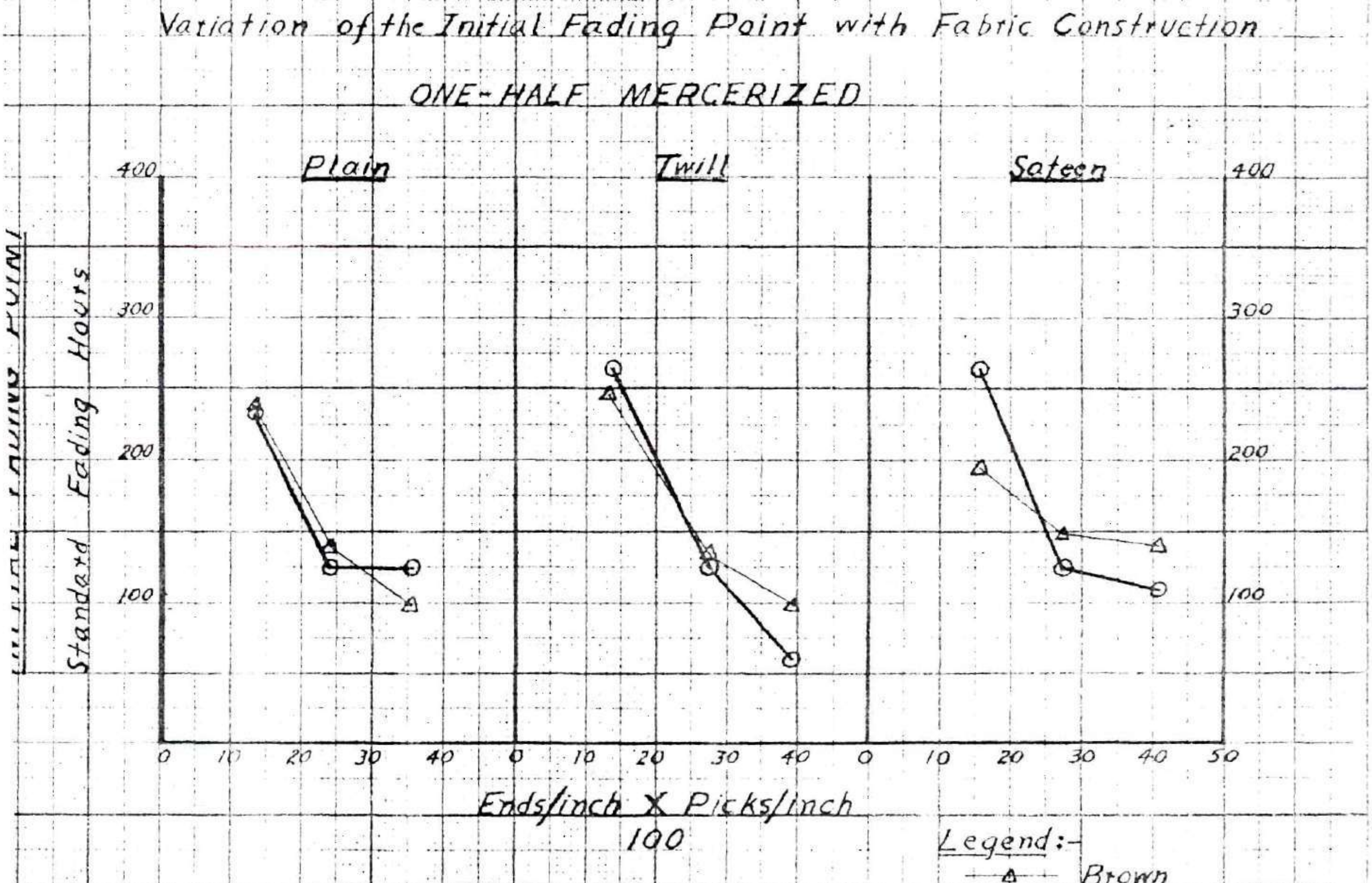
The plain weave showed an upward trend from the loose to the tight construction, for both the khaki and brown colors, and for all degrees of mercerization.

In the twill weaves the khaki color showed the same trend for all degrees of mercerization. The brown was consistent only for the un-mercerized and half-mercerized groups. In the fully mercerized group



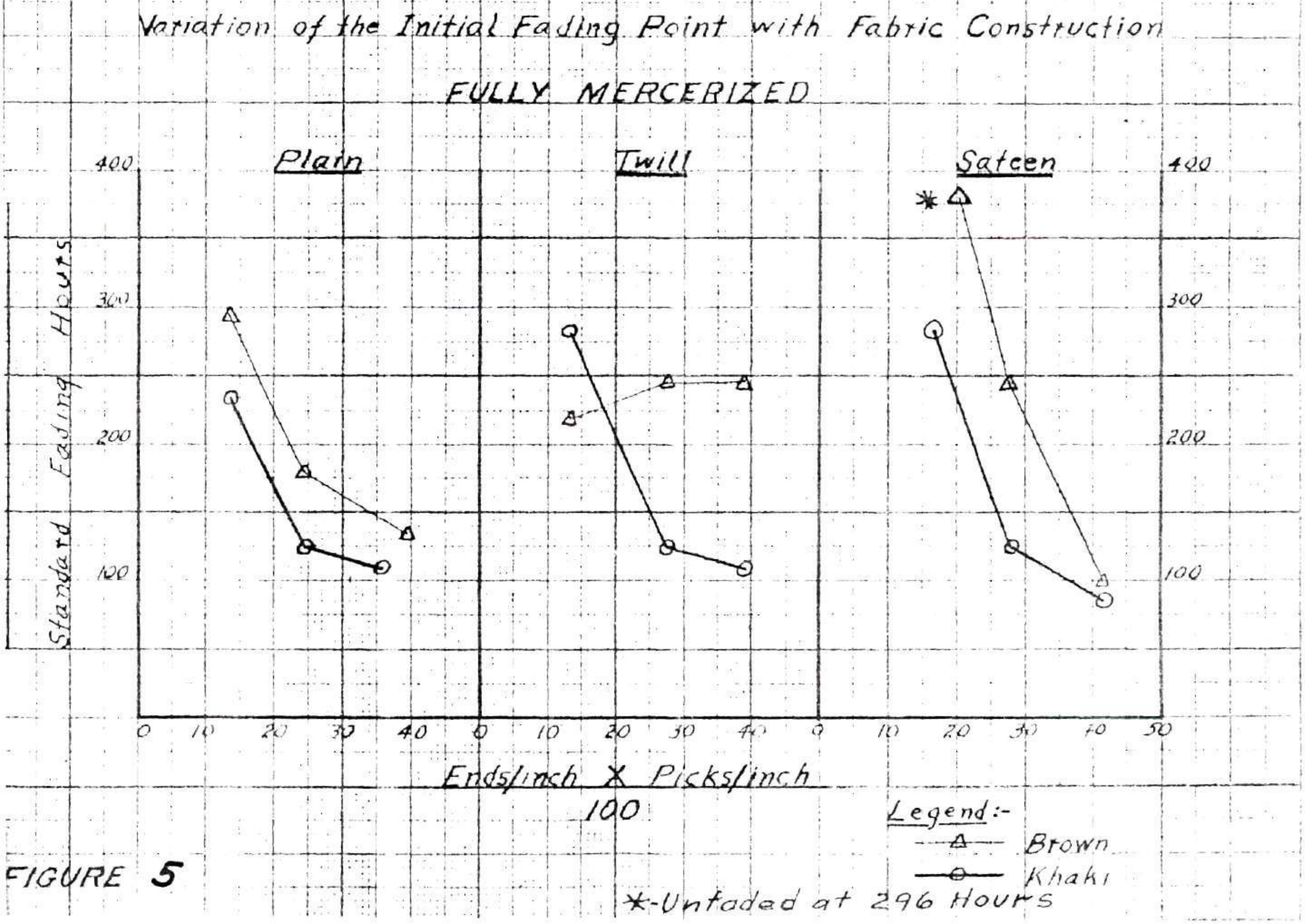
Variation of the Initial Fading Point with Fabric Construction
UNMERCERIZED
Plain
Twill
Sateen
Standard Fading Hours
400
300
200
100
0 10 20 30 40
0 10 20 30 40
0 10 20 30 40 50
Ends/inch X Picks/inch
100
Legend:-
Brown
Khaki

FIGURE 3



Variation of the Initial Fading Point with Fabric Construction
ONE-HALF MERCERIZED
Plain
Twill
Sateen
Standard Fading Hours
400
300
200
100
0
10
20
30
40
50
Ends/inch X Picks/inch
100
Legend:-
Brown
Khaki

FIGURE 4



Variation of the Initial Fading Point with Fabric Construction
FULLY MERCERIZED
Plain
Twill
Sateen
Standard Fading Hours
400
300
200
100
0 10 20 30 40
0 10 20 30 40
0 10 20 30 40 50
Ends/inch X Picks/inch
100
Legend:-
Brown
Khaki
*-Unfaded at 296 Hours

FIGURE 5

As to the sateen weave, the khaki color again showed a clear, upward trend; but in the brown color unmercerized, the loose weave faded first.

Table II shows the index of the average increase in initial fading points for the plain, twill, and sateen weaves, that of the tight weaves being considered 100 per cent.

TABLE II

INDEX OF THE AVERAGE INCREASE
IN INITIAL FADING POINTS

Fabric Construction	Plain Weave		Twill Weave		Sateen Weave	
	Khaki*	Brown*	Khaki*	Brown***	Khaki*	Brown**
Tight	100%	100%	100%	100%	100%	100%
Medium	118%	126%	143%	139%	112%	157%
Loose	211%	241%	343%	263%	219%	412%

*All degrees of mercerization.
**Full and half-mercerization only.
***Unmercerized and half-mercerized only.

2. Light Fading Curves

The results of the examination of light fading at three selected points of fading are shown in Tables V and VI and in Figures 6 and 7. In the brown color all fastness ratings were very high and were practically the maximum to be expected from the best of dyes. There were no appreciable differences among the weaves and constructions. As the fading time progressed, the fading curve was nearly a straight line, and the differences tended to disappear.

Variation of Light Fastness with Fabric Construction - KHAKI

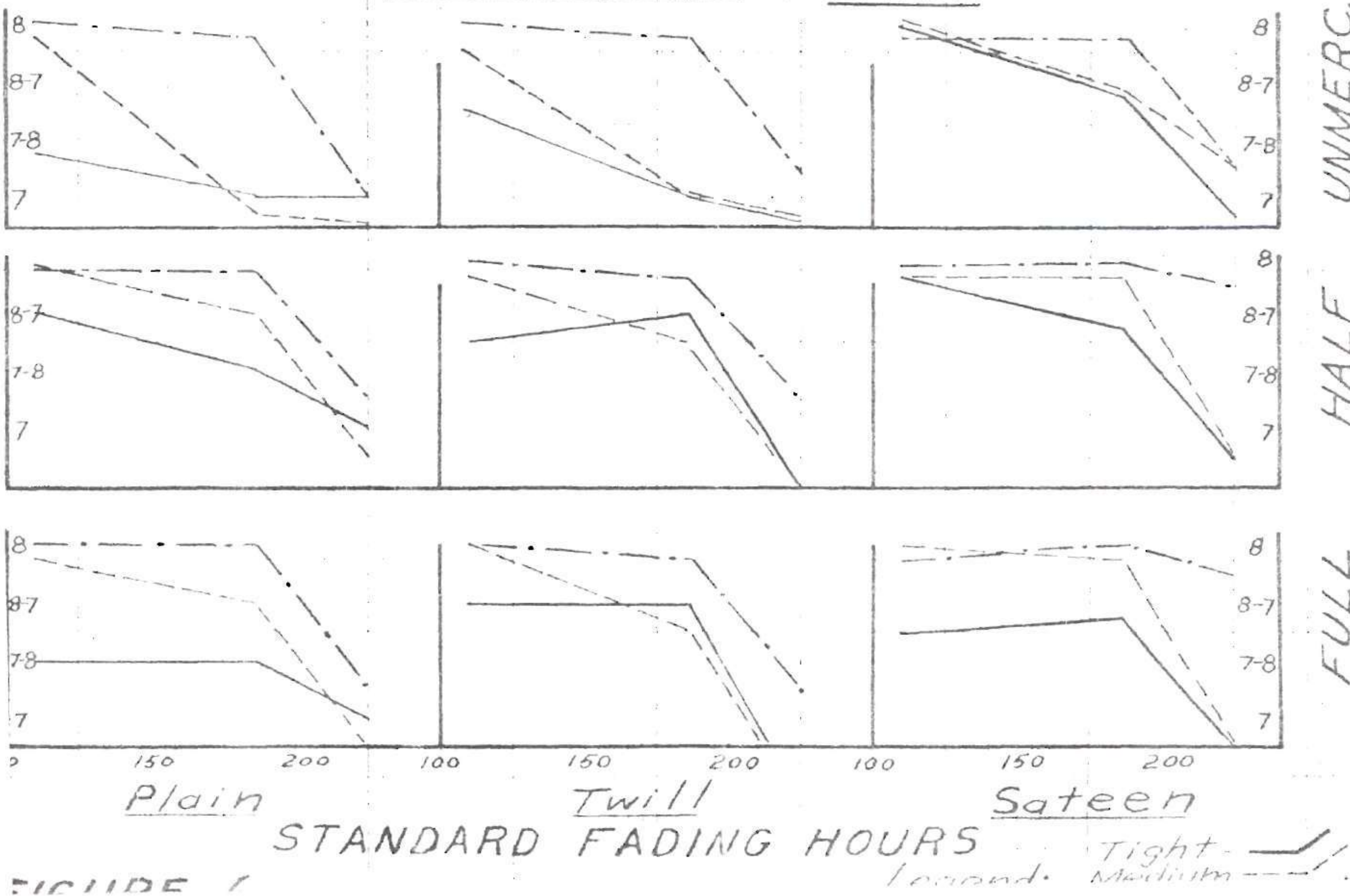


FIGURE 1

Variation of Light Fastness with Fabric Construction - BROWN

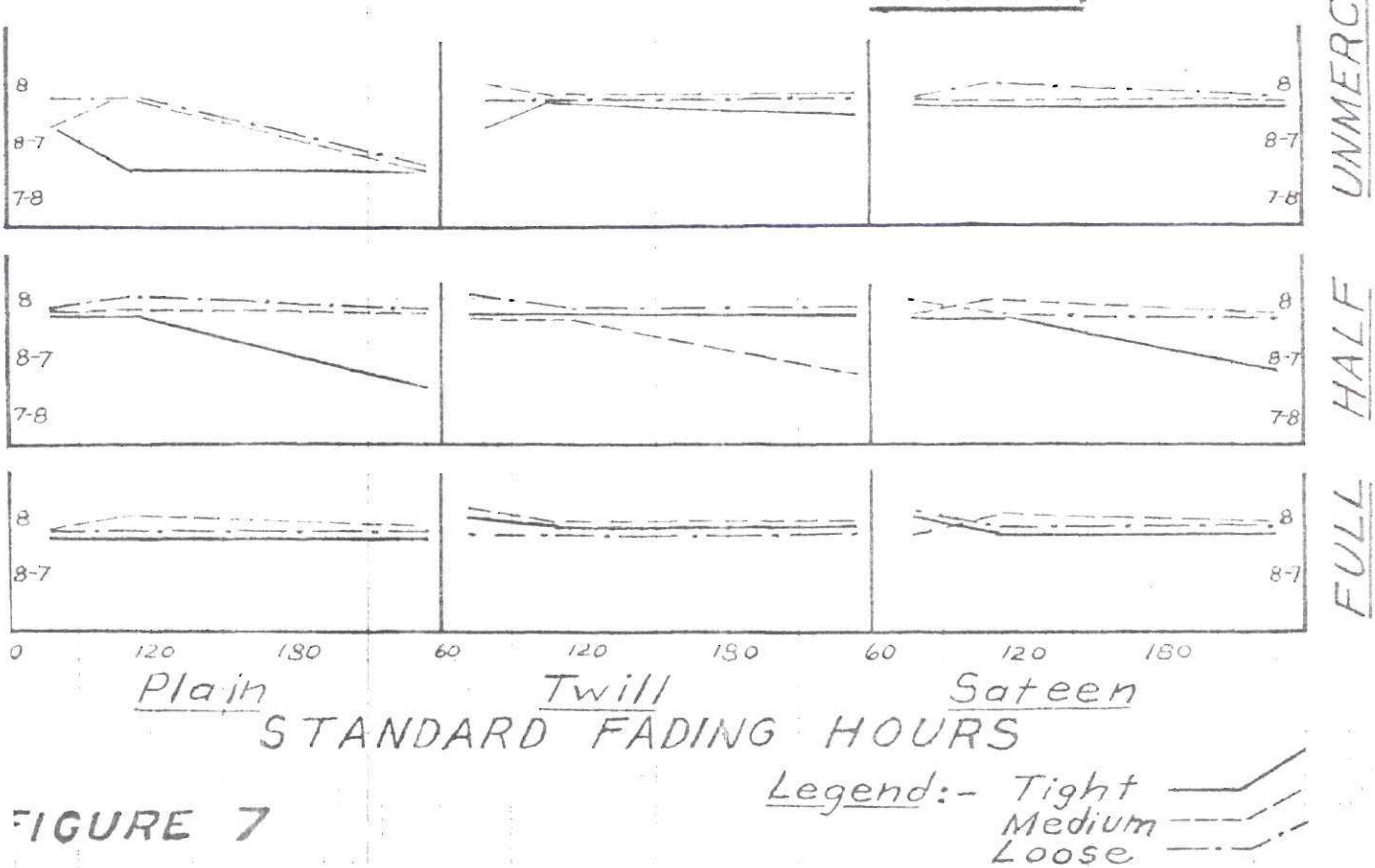


FIGURE 7

The khaki color showed a consistent and distinct trend. The loose weave had the highest rating, the medium next, and the tight weave the lowest. The fading curves were generally parallel for all weaves and constructions and tended to merge at 225 hours.

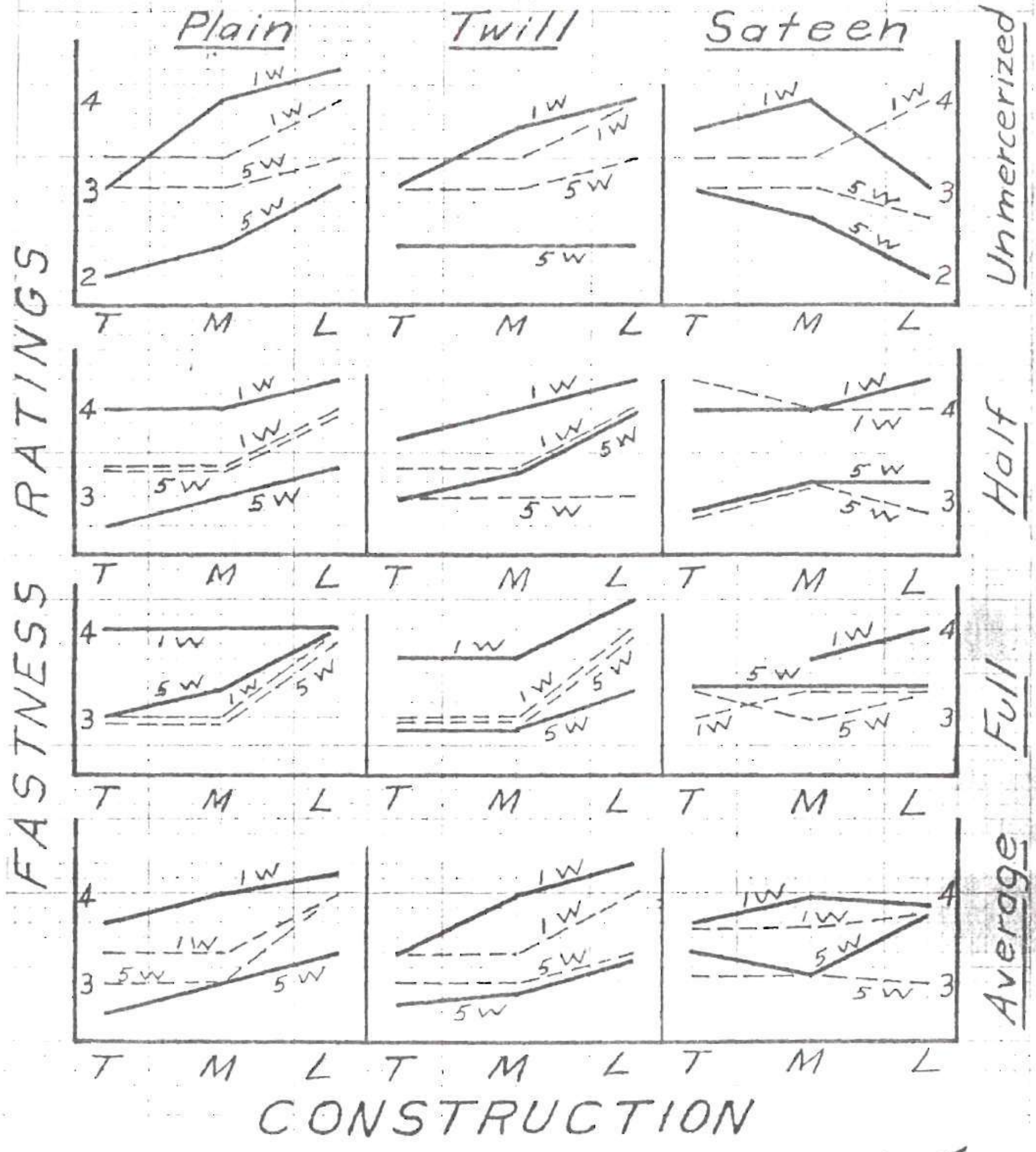
B. Wash Fastness Tests

The evaluation of the test for wash fastness is shown in Table VII and in Figure 8. In general the plain and twill weaves showed a uniform upward trend in fastness from the tight weave as the lowest to the loose weave as the highest.

The sateen weave was erratic. In the khaki color the medium construction appeared the fastest. In the brown color, the loose weave was fastest for the one-wash test but poorest for the five-wash test.

The effect of mercerization was merely to narrow the differences between the brown and the khaki colors. The overall fastness was not improved.

Variation of Wash Fastness with Fabric Construction



Legend:—
Tight - T
Medium - M
Khaki -
Brown -
1-Wash - 1W
5-Washes - 5W

CONCLUSIONS

It has been shown that variations in construction (ends per inch and picks per inch) have produced definite variations in color fastness both to light and to washing.

A. Light Fastness

1. A general increase in fastness from the tight to the loose construction was apparent.

2. The rate of increase in fastness became greater as the number of picks per inch decreased.

3. The plain weave showed this general trend distinctly throughout all the variables of construction, mercerization and dyeing.

4. The results with the sateen and the twill weaves were erratic. No trend was evident.

5. Mercerization raised the general level of all fastness values. It did not alter the general trend.

6. All the khaki specimens exhibited a distinct increase in fastness from tight to loose constructions.

7. The brown specimens showed a less distinct increase in the same direction as that of the khaki. In the "break" test the results were erratic in the twill and sateen weaves. Moreover, the quantitative values of fastness obtained were extremely high for all periods of exposure. The fading curves tended to be straight horizontal lines close together.

B. Wash Fastness

1. The plain and twill weaves displayed an increasing fastness from the tight to the loose construction. This behavior was consistent throughout.

2. The sateen weave was erratic and showed no general trend.

3. Mercerization did not affect the trend in fastness. It merely narrowed the difference between the results of one wash and those of five washes.

RECOMMENDATIONS

This problem offers a very wide field for further investigation. The present paper has combined the manufacturing variables of weaves and constructions with the finishing variables of mercerization and dyeing with vat colors. Two avenues are open for additional research. In one, the results of this paper could be studied in more detail. In the other, different combinations of variables could be examined.

A follow-through on the results of this thesis should entail a more detailed study of the plain or twill weave, fully mercerized, dyed with Ponsol Khaki 2G. These variables are recommended because they have shown a more uniform behavior than the other variables examined. A series of observations should substantiate each of the results already obtained in the tests for initial fading points, light fading curves, and wash fastness. It would be advisable to investigate more than three periods of exposure in the fade-ometer, in order better to ascertain the shapes of the fading curves. Moreover, measurement of fading by means of the spectrophotometer would offer a closer and more accurate means of measuring the amount of fading.

Many other combinations of variables could be examined. The effect of different counts and twist could be studied, as well as the behavior of additional weaves and constructions. The range in picks per inch from about 75 to about 30 would be most suitable for further study. Graduations of ten are recommended. As to dyes, additional ones with wide variations in fastness should be examined.

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APPENDIX

TABLE III

COUNTS OF DYED CLOTH

Fabric Construction	Unmercerized			Half-Mercerized			Fully Mercerized		
	Sley*	Picks**	Product Sley x Picks	Sley*	Picks**	Product Sley x Picks	Sley*	Picks**	Product Sley x Picks
Plain(Tight)	69	54	3728	67	53	3551	69	52	3588
Plain(Medium)	66	37	2445	67	36	2412	68	36	2448
Plain(Loose)	63	21	1323	63	21	1323	65	21	1365
Twill(Tight)	70	58	4060	68	58	3944	70	56	3920
Twill(Medium)	69	41	2829	68	41	2788	69	40	2760
Twill(Loose)	65	21	1365	64	21	1344	67	20	1340
Sateen(Tight)	67	61	4087	67	61	4087	70	59	4130
Sateen(Medium)	67	42	2814	65	42	2730	68	41	2788
Sateen(Loose)	66	24	1585	65	24	1560	67	24	1608

*Ends per inch.
**Picks per inch.

TABLE IV

INITIAL FADING POINTS OF DYED FABRICS
(In Standard Fading Hours)

Fabric Construction	Unmercerized		Half-Mercerized		Fully Mercerized	
	Khaki	Brown	Khaki	Brown	Khaki	Brown
Plain (Tight)	85	99	125	99	109	135
Plain (Medium)	125	99	125	140	125	181
Plain (Loose)	206	266	234	238	234	296
Twill (Tight)	59	89	59	99	109	247
Twill (Medium)	75	126	125	135	125	247
Twill (Loose)	234	247	264	247	283	220
Sateen (Tight)	125	99	109	140	85	99
Sateen (Medium)	109	247	125	149	125	247
Sateen (Loose)	151	135	264	196	283	None at 296

TABLE V

EVALUATION OF FASTNESS TO LIGHT TESTS BY VISUAL EXAMINATION
(Khaki Samples)

Fabric Construction	Unmercerized			Half-Mercerized			Fully Mercerized		
	109 Std.Hrs.	187 Std.Hrs.	225 Std.Hrs.	109 Std.Hrs.	187 Std.Hrs.	225 Std.Hrs.	109 Std.Hrs.	187 Std.Hrs.	225 Std.Hrs.
Plain(Tight)	7-8^{t}R	7	7	8-7	7-8	7	7-8	7-8	7
Plain(Medium)	8^{t}R	7^{t}R	7R	8	8-7	7R	8^{t}Y	8-7	7R
Plain(Loose)	8	8^{t}R	7R	8	8	7-8R	8	8	7-8R
Twill(Tight)	8-7R	7	7R	8-7W	8-7	7-6R	8-7	8-7	7-6R
Twill(Medium)	8R	7	7R	8^{t}R	8-7R	7-6R	8	8-7R	7-6R
Twill(Loose)	8	8^{t}R	7-8R	8	8^{t}R	7-8R	8	8^{t}R	7-8R
Sateen(Tight)	8	8-7^{t}R	7R	8^{t}R	8-7^{t}R	7R	8-7Y	8-7^{t}R	7R
Sateen(Medium)	8	8-7^{t}R	7-8R	8^{t}R	8^{t}R	7R	8	8^{t}R	7R
Sateen(Loose)	8^{t}R	8^{t}R	7-8R	8	8	8R	8^{t}R	8	8R

SYMBOLS

R - Redder
W - Weaker
Y - Yellower
^{t}R - Trace Redder
^{n}R - Noticeably Redder

CLASSIFICATIONS

The numbers, 1-8, represent the standard classifications for color fastness as set forth in the "Tentative Test Method No. 16-45" of the American Association of Textile Chemists and Colorists.

TABLE VI

EVALUATION OF FASTNESS TO LIGHT TESTS BY VISUAL EXAMINATION
(Brown Samples)

Fabric Construction	Unmercerized			Half-Mercerized			Fully Mercerized		
	80 Std.Hrs.	110 Std.Hrs.	238 Std.Hrs.	80 Std.Hrs.	110 Std.Hrs.	238 Std.Hrs.	80 Std.Hrs.	110 Std.Hrs.	238 Std.Hrs.
Plain(Tight)	$8^{n}R$	8-7R	8-7R	$8^{t}R$	$8^{t}R$	8-7R	$8^{t}R$	$8^{t}R$	$8^{t}R$
Plain(Medium)	$8^{n}R$	$8^{t}R$	8-7R	$8^{t}R$	$8^{t}R$	$8^{t}R$	$8^{t}R$	8	$8^{t}R$
Plain(Loose)	$8^{t}R$	$8^{t}R$	8-7R	$8^{t}R$	8	$8^{t}R$	$8^{t}R$	$8^{t}R$	$8^{t}R$
Twill(Tight)	$8^{n}R$	$8^{t}R$	8R	$8^{t}R$	$8^{t}R$	$8^{t}R$	8	$8^{t}R$	$8^{t}R$
Twill(Medium)	8	$8^{t}R$	$8^{t}R$	$8^{t}R$	$8^{t}R$	$8\text{-}7^{t}R$	8	$8^{t}R$	$8^{t}R$
Twill(Loose)	$8^{t}R$	$8^{t}R$	$8^{t}R$	8	$8^{t}R$	$8^{t}R$	$8^{t}R$	$8^{t}R$	$8^{t}R$
Sateen(Tight)	$8^{t}R$	$8^{t}R$	$8^{t}R$	$8^{t}R$	$8^{t}R$	$8\text{-}7^{t}R$	8	$8^{t}R$	$8^{t}R$
Sateen(Medium)	$8^{t}R$	$8^{t}R$	$8^{t}R$	$8^{t}R$	8	$8^{t}R$	$8^{t}R$	8	$8^{t}R$
Sateen(Loose)	$8^{t}R$	8	$8^{t}R$	8	$8^{t}R$	$8^{t}R$	8	$8^{t}R$	$8^{t}R$

SYMBOLS

R - Redder
W - Weaker
Y - Yellower
^{t}R - Trace Redder
^{n}R - Noticeably Redder

CLASSIFICATIONS

The numbers, 1-8, represent the standard classifications for color fastness as set forth in the "Tentative Test Method No. 16-45" of the American Association of Textile Chemists and Colorists.

TABLE VII

EVALUATION OF WASHING TEST SAMPLES BY VISUAL INSPECTION

Fabric Construction	Unmercerized				Half-Mercerized				Fully Mercerized			
	1-Wash		5-Washes		1-Wash		5-Washes		1-Wash		5-Washes	
	Brown	Khaki	Brown	Khaki	Brown	Khaki	Brown	Khaki	Brown	Khaki	Brown	Khaki
Plain(Tight)	3-4D	3G	3D	2G	3-4D	4G	3-4D	3-2GD	3D	4GY	3D	3GD
Plain(Medium)	3-4D	4G	3D	2-3G	3-4D	4G	3-4D	3GD	3D	$4^{t}G$	3D	3-4GD
Plain(Loose)	4D	4-5G	3-4D	3G	4D	4-5G	4D	3-4GD	4D	4GD	4D	4G
Twill(Tight)	3-4D	3G	3D	2-3G	3-4D	4-3G	3D	3G	3D	4-3GD	3D	3GD
Twill(Medium)	3-4D	4-3G	3D	2-3G	3-4D	4G	3D	3-4G	3D	4-3GD	3D	3GD
Twill(Loose)	4D	4G	3-4D	2-3G	4D	4-5G	3D	4G	4D	4-5GD	4D	3-4GD
Sateen(Tight)	3-4D	4-3G	3D	3G	4-5D	$4^{n}G$	3D	3G	3D		3-4D	3-4GD
Sateen(Medium)	3-4D	4G	3D	3-2G	4D	$4^{n}G$	3-4D	3-4G	3-4D	4-3GD	3D	3-4GD
Sateen(Loose)	4D	3G	3-2D	2G	4D	$4\text{-}5^{t}G$	3D	3-4G	3-4D	4G	3-4D	3-4GD

SYMBOLS

D - Duller
G - Greener
Y - Yellower
^{t}G - Trace Greener
^{n}G - Noticeably Greener

RATINGS

No.	Fastness	Fading
5	Very Good	Negligible or None
5-4	Very Good	Trace
4	Good	Noticeable
3	Fairly Good	Appreciable
2	Moderate	Considerable
1	Poor	Very Much

TABLE VIII

CALIBRATION DATA OF STANDARD FADING PAPER NO. 1554
EXPOSED WITH EACH FADE-OMETER RUN
(amber filter)

No.	Machine Hours	% Reflectance* 0°	90°	Aver.	Equiv. Standard Fading Hours	Equiv. Standard Fading Hours as Measured by the National Bureau of Standards
1 2	10	21.7	21.9	21.8	15.6	16.0
3	20	26.0	26.0	26.0	27.6	27.9
4	10	20.8	20.9	20.9	13.0	13.4
5	20	25.4	25.4	25.4	25.8	25.9
6	20	27.0	27.0	27.0	30.8	
7	15	22.6	22.6	22.6	17.8	17.8
8	20	29.2	29.2	29.2	38.7	38.6
9	24	28.7	28.7	28.7	36.6	36.2
10	21	26.8	26.8	26.8	30.1	30.1
11	24	27.7	28.0	27.9	34.0	34.2
12	21	26.5	26.5	26.5	29.4	29.4
13	15	24.6	24.6	24.6	23.0	23.0
14	20	27.0	27.0	27.0	30.8	30.8
15	20	25.4	25.4	25.4	25.8	
16	20	25.5	25.5	25.5	26.0	
17	12	21.4	21.4	21.4	14.5	
18	8-1/4	19.4	19.4	19.4	9.6	
19	20	25.4	25.4	25.4	25.8	
20	12	23.5	23.5	23.5	20.1	
21	10	20.5	20.5	20.5	12.2	
22	12	24.2	24.2	24.2	22.2	
23	20	24.7	24.9	24.8	24.0	
24	20	26.8	26.8	26.8	30.1	
25	10	20.5	20.5	20.5	12.2	
26	12	21.2	21.2	21.2	14.2	
27	12	22.0	22.0	22.0	16.1	
28	12	21.5	21.6	21.6	15.1	
29	12	21.5	21.5	21.5	15.0	
30	20	24.8	24.8	24.8	24.0	
31	20	26.0	26.0	26.0	27.6	
32	20	26.6	26.6	26.6	29.7	
33	16-1/2	23.2	23.2	23.2	19.5	

*Measured on the photovolt reflectometer, in terms of freshly cut magnesium oxide as 100 per cent.